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(54) CIRCUIT FOR AND METHOD OF SLOWING A MULTIPHASE INDUCTION MOTOR

(71) We, MYRON ZUCKER, INC, a corporation organised and existing under the laws of the State of Michigan, United States of America, of 708 West Long Lake Road, Bloomfield Hills, Michigan, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a circuit for and a method of slowing an induction motor and relates more specifically to placing direct current electrolytic capacitors connected in a wye configuration across the separate phase terminals of a multiphase induction motor it is desired to slow, with the electrodes of the capacitors of one polarity connected together to provide dynamic braking for the motor. The capacitors may be automatically placed across the motor on failure of the driving energy for the motor to provide a fail-safe motor slowing feature.

In the past, electric motors have often been braked by friction brakes using conventional brake drums and shoes sometimes applied with electromagnetic or hydraulic power. Electric braking of the motor in the past has often taken the form of plug reversing or capacitor braking or direct current injection braking or other dynamic braking.

These prior braking methods have in the past been deficient in one or more ways. Thus, friction braking is not fast enough for many uses and generates considerable heat and often noise as well as wear in the brake system. Plug reversing introduces very high system currents and thus excessive heating and must be stopped at a precise moment or actual reversing of the motor will occur. The effect of direct current injection into an electric motor is minimal at high speed and can produce considerable motor heating.

Dynamic braking produces less heat. However, in the past relatively large, expensive capacitors have been necessary to provide the dynamic motor braking or slowing required. Further, whereas electrolytic capacitors have been used in dynamic braking of alternating current motors in the past, they have been alternating current capacitors which are more complicated and more expensive than direct current capacitors.

In accordance with the invention there is provided a circuit for slowing a multiphase induction motor including a plurality of motor terminals, comprising a direct current electrolytic capacitor associated with each phase, each capacitor having a pair of electrodes of opposite predetermined polarity, means connecting the electrodes of one polarity of each capacitor together and means which connect each capacitor electrode of the other polarity to a respective motor terminal in response to switching off of energy to the motor whereby the capacitors are connected in wye configuration to the motor terminals.

A further aspect of the invention provides a method of slowing a three-phase induction motor comprising connecting direct current polarized electrolytic capacitors, connected in a wye configuration with electrodes of one polarity connected together, across the terminals of the motor in response to disconnection of energy to the motor.

An embodiment of the invention will be described, by way only of example, with reference to the drawing, in which:—

Figure 1 is a schematic diagram of a circuit for slowing an induction motor in accordance with the method of the invention and constructed in accordance with the invention; and

Figure 2 is a graph illustrating motor speed and time during slowing of a motor with the circuit of Figure 1, in accordance with modifications of the invention.

As shown best in Figure 1, the motor 10 is a three-phase induction motor having the internal phase windings 12, 14 and 16 connected in a wye configuration with one end joined at the common point 18. The other ends of the phase windings 12, 14 and 16 of the motor 10 are connected at motor phase

terminals 20, 22 and 24 to separate motor energy feed conductors 26, 28 and 30 respectively.

The conductors 26, 28 and 30 are connected through motor contactor contacts 34A, 34B and 34C to a source of three-phase alternating electrical energy 36. Relay coil 32 is placed across the conductors 28 and 30 as shown.

In operation, the contacts 34A, 34B and 34C are closed by a motor contactor control circuit, which is not shown, to pass energy from the three-phase electrical energy source 36 to the motor 10 whereby the motor 10 is brought up to operating speed. During this time, the relay coil 32 which is connected across the conductors 28 and 30 will be energized to open the relay contacts 32A, 32B and 32C.

In accordance with the invention, direct current electrolytic capacitors 38, 40, 42, 44, 46 and 48 are also provided connected in series pairs in each branch of a wye configuration as shown in Figure 1. The wye configuration of direct current electrolytic capacitors 38 through 48 is connected across the three phases of the induction motor 10 through the relay contacts 32A, 32B and 32C, also as shown in Figure 1.

The electrolytic capacitors 38 through 48 are effective on opening of contacts 34A, 34B and 34C and closing of contacts 32A, 32B and 32C to slow the speed of the motor 10 to approximately 15 percent of the running speed thereof as indicated generally along line 52 in the motor speed time graph of Figure 2. Substantial slowing of the induction motor 10 may thus be accomplished more rapidly and with less heat, noise and complicated and expensive circuitry than has previously been possible with known motor braking or slowing circuits. Other forms of braking such as mechanical braking may be used to bring the motor 10 to a complete stop, if desired, as shown along line 78 in Figure 2.

It will be understood that either the direct current electrolytic capacitors 38, 42 and 46 or the direct current electrolytic capacitors 40, 44 and 48 could by themselves provide dynamic motor braking in accordance with the invention. The capacitors 38 and 40, the capacitors 42 and 44 and capacitors 46 and 48 have been connected in series in the separate branches of the wye configuration to increase the voltage handling capacity of the capacitor wye configuration which is necessary during initial motor slowing.

In the series connection of the pairs of capacitors 38 and 40, 42 and 44, and 46 and 48, it will be particularly noted that the negative electrode of the capacitors 38, 42 and 46 is connected to the positive electrode of the capacitors 40, 44 and 48, and that the negative electrode of capacitors 40, 44 and 48 are connected to a common or neutral point 50. The positive electrodes of the direct current electrolytic capacitors 38, 42 and 46 are connected through the contacts 32A, 32B and 32C directly to the conductors 30, 28 and 26.

If there were a single capactor in each branch of the wye configuration of capacitors in Figure 1, the negative electrodes of all of the direct current electrolytic capacitors would be connected together, while the positive electrodes would be separately connected to the conductors 26, 28 and 30.

Such connection is essential to prevent failure of the capacitors due to a large inverse voltage thereacross. With the connections illustrated, the capacitors protect each other during the inverse polarity periods which permits the use of the relatively cheap direct current electrolytic capacitors in the motor slowing circuit of the invention as illustrated in Figure 1.

Further with regard to the operation of the motor slowing circuit in Figure 1, when it is desired to slow the motor 10, the contacts 34A, 34B and 34C are opened. as a result of the opening of the contacts 34B and 34C, the energy to the relay coil 32 is lost so that the relay contacts 32A, 32B and 32C which have been open during the energizing of the induction motor 10 are caused to return to their closed condition illustrated in Figure 1. The electrolytic capacitors 38 through 48 connected in the wye configuration shown are thus connected across the three phases of the induction motor 10 to provide dynamic braking for slowing the motor 10 as generally illustrated by line 52 in Figure 2.

If it is desired to completely stop the motor 10, additional braking such as mechanical braking may be used (as generally illustrated by line 78 in Figure 2) when the motor speed has been reduced to for example 15 percent of its initial speed by the dynamic braking of the capacitors 38 through 48.

In this operation it will be particularly noted that should the energy to the motor 10 fail for any reason on the lines 28 and 30, the relay coil 32 will be de-energized, closing all the contacts 32A, 32B and 32C whereby the dynamic braking indicated above will occur automatically on failure or for example the power supply 36. A fail-safe feature is thus provided in the motor slowing circuit of Figure 1. The fail-safe feature is optional and if not required would allow the energizing of the relay coil 32 by the motor contactor control circuit or some other circuit as desired.

In a modification, a separate wye configuration of direct current electrolytic capacitors 54, 56, 58, 60, 62 and 64 is provided connected in parallel with the wye configuration of the capacitors 38 through 48 to increase the capacitance available for added dynamic braking. Due to the addition of capacitors 54 through 64, motor slowing

may proceed as indicated by line 65 on the graph of Figure 2.

The provision of the added capacitance in a separate wye configuration rather than merely adding the additional capacitance to the capacitors 38 through 48 is desirable since should one capacitor be shorted in any individual wye configuration, it will tend to cause failure of the other capacitors in the same wye configuration. Falure of all the capacitors in one wye configuration will, however, have little effect on the capacitors in a separate parallel wye configuration if the neutral points of the wye configurations are kept isolated so that even on failure of all the capacitors of one wye configuration 38 through 48, for example, substantial motor slowing will be possible by the action of the still operative second group of capacitors 54 through 64.

In the event of failure of one wye configuration, the motor braking by the other wye configuration will be sufficiently slower to indicate failure of one or more capacitors in the one wye configuration to operating personnel.

The capacitors 66 and 68 and the capacitor 70 are positioned across the conductors 26 and 28, 28 and 30 and 26 and 30 respectively to maintain the motor voltage during switching of the contacts 32A through 32C. Capacitors 66, 68 and 70 are charged during energizing of the motor, when they also provide phase angle correction, and discharge through the motor windings when the energy to the motor is cut off.

Resistors 72, 74 and 76 which are connected in wye configuration and placed in parallel with the wye configurations of capacitors 38 through 48 and 54 through 64 further enhance the slowing of the motor 10. The resistors 72, 74 and 76 need not be in wye configuration.

It will thus be seen that a circuit for and a method of slowing a multiphase induction motor have been presented which is particularly simple, economical and efficient.

While one embodiment and one modification of the invention have been considered in detail, it will be understood that other modifications and embodiments are contemplated within the scope of the appended claims.

WHAT WE CLAIM IS:—

1. A circuit for slowing a multiphase induction motor including a plurality of motor terminals, comprising a direct current electrolytic capacitor associated with each phase, each capacitor having a pair of electrodes of opposite predetermined polarity, means connecting the electrodes of one polarity of each capacitor together and means which connect each capacitor electrode of the other polarity to a respective motor terminal in response to switching off of energy to the motor whereby the capacitors are connected in wye configuration to the motor terminals.

2. A circuit as set forth in Claim 1 wherein the means which connect the electrodes of the other polarity to the respective motor terminals is also operable in response to failure of the energy supply for the motor, to provide a fail-safe motor slowing action.

3. A circuit as set forth in Claim 1 or Claim 2 wherein the motor is a three-phase induction motor.

4. A circuit as set forth in Claim 3 and further including an additional electrolytic capacitor in series with each of the other capacitors in each branch of the wye configuration with opposite polarity electrodes of the capacitors in each wye branch being connected together to increase the voltage handling capability of the motor slowing circuit.

5. A circuit as set forth in Claim 3 or Claim 4, including a further plurality of electrolytic capacitors connected in a wye configuration in parallel with the first-mentioned wye configuration of capacitors and with the neutral points of the wye configurations being isolated from each other to protect each wye configuration of capacitors against damage caused by failure of a capacitor in the other wye configuration.

6. A circuit as set forth in any of Claims 3 to 5 and including further capacitors connected across the motor terminals for maintaining motor voltage during switching.

7. A circuit as set forth in any of Claims 3 to 6 wherein the means which connect the capacitor electrodes of the other polarity to the motor terminals includes a relay coil connected across two of the motor terminals and a set of relay contacts connecting each of the motor terminals to the corresponding branch of the wye configuration, the contacts opening in response to energizing of the relay coil.

8. A method of slowing a three-phase induction motor comprising connecting direct current, polarized electrolytic capacitors, connected in a wye configuration with electrodes of one polarity connected together, across the terminals of the motor in response to disconnection of energy to the motor.

9. The method as set forth in Claim 8 in which the connection of the capacitors across the terminals occurs in response to failure of the energy supply to the motor to provide fail-safe operation of the motor.

10. A circuit for slowing a three-phase induction motor which induction motor includes three phase windings connected to respective motor terminals, respective lead wires being connected to the motor terminals for connection to respective phases of a three-phase source of alternating electrical energy, comprising first contacts in the lead wires between the source of electrical energy and the motor which on being closed permit energization of the motor by the source of

electrical energy, three direct current electrolytic capacitors each having a pair of electrodes of opposite predetermined polarity, means connecting the electrodes of one polarity of each capacitor together, means connecting each of the other electrodes of the capacitors to a respective one of the lead wires between the first contacts and the motor terminals, a relay coil connected across two of the three-phase lead wires between the first contacts and the motor terminals whereby the relay coil is energized only when the first contacts are closed, and second contacts in each of the means connecting the other electrodes of the electrolytic capacitors to the respective lead wires operable by the relay coil to be open when the coil is energized and closed when the coil is de-energized, whereby the electrolytic capacitors are connected in wye configuration to the motor terminals on de-energizing the motor by opening the first contacts.

11. A circuit as set forth in Claim 10 and further including a phase angle correction capacitor extending between each of the separate lead wires and each of the other lead wires between the source of electrical energy and the motor terminals.

12. A circuit as set forth in Claim 10 or Claim 11 and further including three additional direct current electrolytic capacitors each having a pair of electrodes of opposite predetermined polarity, the capacitors being connected in wye configuration with the electrodes of one polarity connected together and the electrodes of the other polarity connected to said second contacts so that the additional electrolytic capacitors are in parallel with the first three electrolytic capacitors to increase the slowing capability of the circuit.

13. A circuit for slowing a multiphase induction motor substantially as hereinbefore described with reference to the accompanying drawing.

14. A method of slowing a multiphase induction motor substantially as hereinbefore described with reference to the accompanying drawing.

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1390432 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

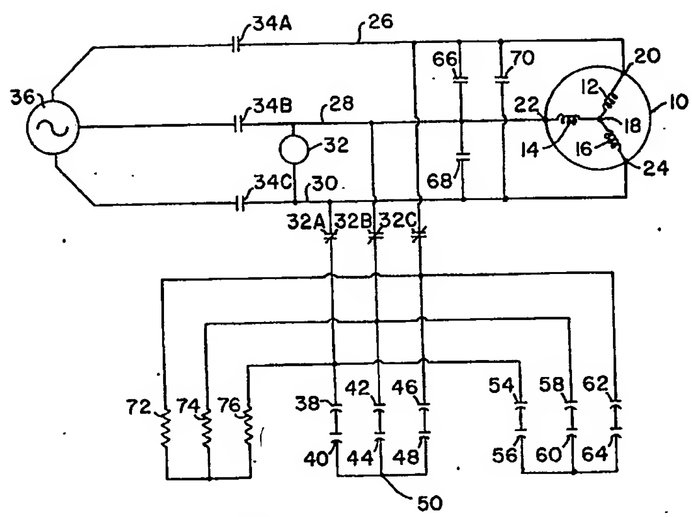

FIG.1

FIG.2